APPENDIX H

Flap-Edge Blowing Experiments

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This Appendix documents the salient results from an effort to mitigate the so-called flap-edge noise generated at the split between a flap edge that is deployed and the un-deployed flap. Utilizing a Coanda surface installed at the flap edge, steady blowing was used in an attempt to diminish the vortex strength resulting from the uneven lift distribution. The strength of this lifting vortex was augmented by steady blowing over the deployed flap. It documents the salient results from an effort to mitigate the so-called flap-edge noise generated at the split between a flap edge that is deployed and the un-deployed flap. Utilizing a Coanda surface installed at the flap edge, steady blowing was used in an attempt to diminish the vortex resulting from the uneven lift distribution. The strength of this lifting vortex was augmented by steady blowing over the deployed flap.

The test article for this study was the same 2D airfoil used in the steady blowing program reported earlier (also used in pulsed blowing tests, see Appendix G), however its trailing edge geometry was modified. An exact duplicate of the airfoil shape was made out of fiberglass with no flap, and in the "clean" configuration. It was attached to the existing airfoil to make an airfoil that has half of its flap deployed and half un-deployed. Figure 1 shows a schematic of the planform showing the two areas where steady blowing was introduced. The flap-edge blowing or the auxiliary blowing was in the direction normal to the freestream velocity vector. Slot heights for the blowing chambers were on the order of 0.014 inches.

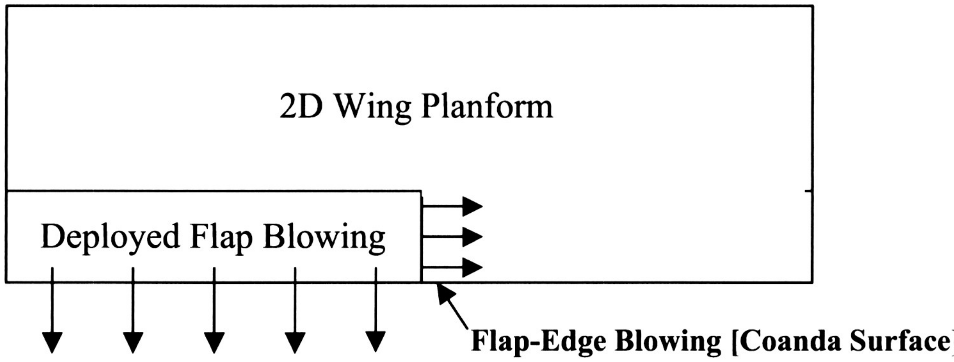

Figure 1. Schematic of Flap-Edge Blown 2D airfoil.

Figure 2 shows this airfoil installed in GTRI's Anechoic Free Simulation Facility.

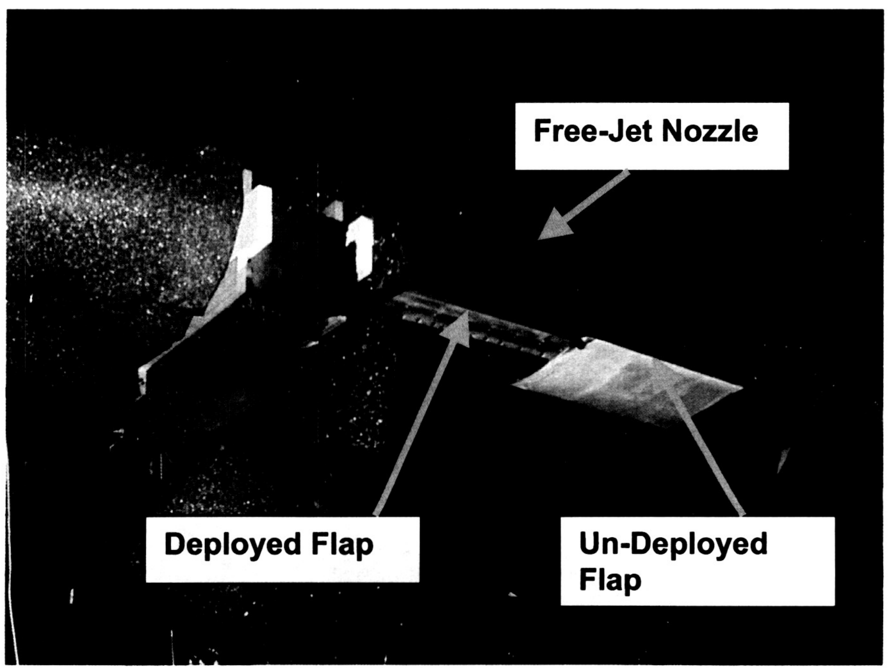

Figure 2. Test article installed in Anechoic Flight Simulation Facility.

Data Acquisition

Flow Data

Total pressures in the blowing plenums were recorded with Kulite pressure transducers. Facility ambient pressure and temperature were monitored. The simulated freestream velocity was computed from static pressure measurements made around the circumference of the nozzle bringing air into the facility. A Labview data acquisition program was written on a Windows platform to collect the pressures from the venturi and the wind tunnel. All flow data was stored in retrievable files on the computer.

Acoustic Data

Acoustic data were acquired with 1/4-inch B&K condenser microphones using B&K Nexus power supplies and amplifiers. These microphones were placed on a polar arc directly beneath the wing model. Using the facility's jet exhaust axis as the 0^0 polar angle, eight microphones were placed 10^0 apart from 100^0 to 30^0. Figure 3 shows this set up. All miccropones, except the 100^0 and the 30^0, were located 10 feet. The data from the 100^0 and 30^0 microphones were corrected to a distance of 10 feet. Furthermore, all acoustic data was corrected for atmospheric absorption, free-field response, and the microphone grid effect. Pressure time histories were acquired on a Multi-Channel Signal Analyzer for FFT analysis running on a Pentium-based Windows computer platform.

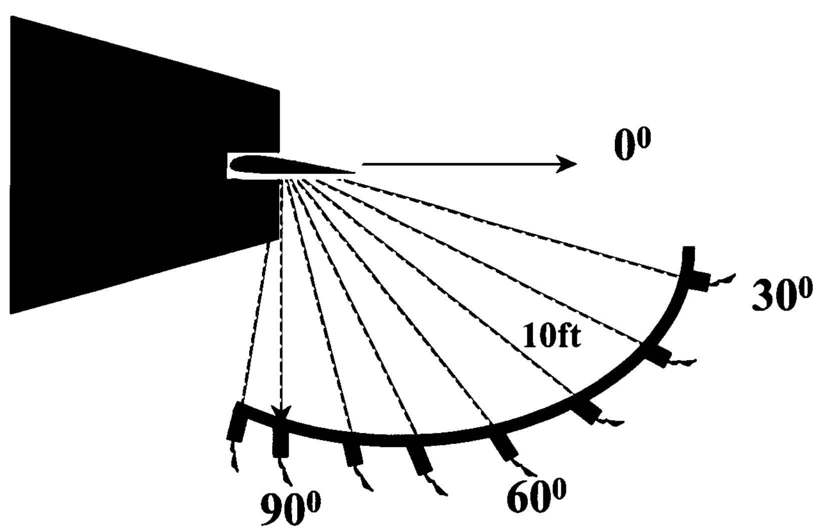

Figure 3. Farfield microphone set-up in Anechoic Flight Simulation Facility.

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Test Conditions

Test conditions concentrated on a freestream condition of 100 ft/s. Two levels of blowing were tested for both the main flap and the flap-edge blowing slot. These were approximately 1 and 3 psig. Combinations of these blowing levels were used as acoustic test points. Note that data presented here does not account for the free jet shear layer effects or atmospheric absorption. Furthermore, the data has not been corrected for the microphone grid and free-field effects. This is of small consequence since we are examining differences of configurations tested in the same facility in the same time period.

Results

With a freestream velocity of 100 ft/s and no blowing operating, the radiated farfield noise character of the wing is dominated by noise below 1000 Hz. Figure 4 shows the SPL (Sound Pressure Level) spectrum at a polar angle of 90 degrees of such a case.

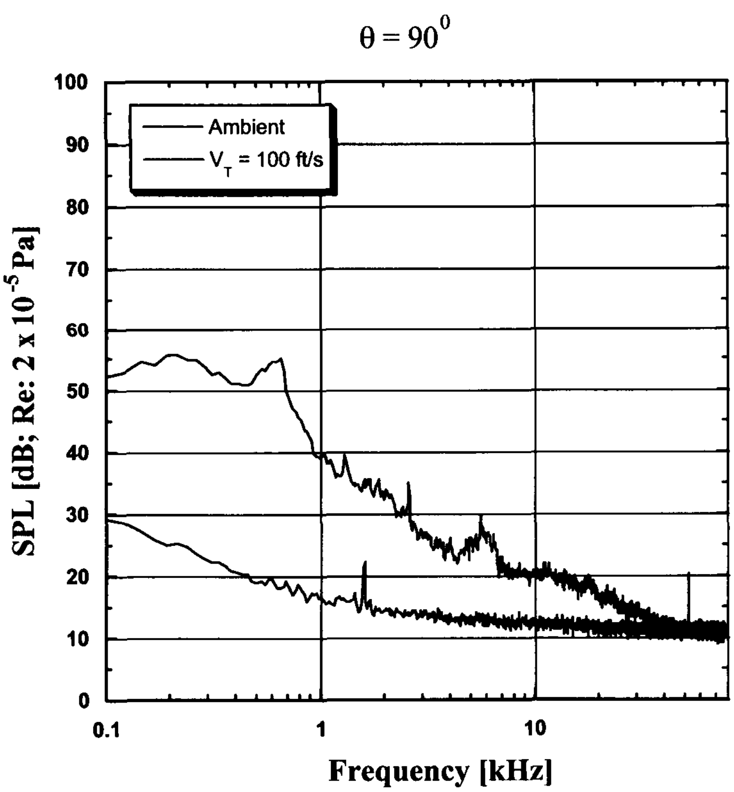

Figure 4. Farfield noise of wing with no blowing at freestream velocity of 100 ft/s, $\theta = 90^0$.

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A tuft placed at the flap edge (at the midspan location of the trailing edge), was visualized with a strobe light and the lift vortex due to the increased lift of the flap, was clearly visible. Figure 5 shows a photograph of this effect.

Figure 5. Lift vortex visualized with tuft at midspan trailing edge.

The effect of the flap-edge blowing was first examined without any main flap blowing operating. At a freestream velocity of 100 ft/s, the auxiliary or flap-edge blowing was operated at 0, 1 and 3 psig total pressure conditions. Figure 6 shows the resulting farfield acoustic SPLs at polar angles of 30, 60, and 90 degrees, respectively. Clearly, the small jet over the Coanda surface has an impact on the radiated noise above 6000 Hz in the 1 psig case and 1000 Hz in the 3 psig case. At $\theta = 90^0$, the intermediate pressure of 1 psig seems to reduce the noise peak around 600 Hz, but it is elevated again at a pressure of 3 psig.

Figure 7 shows spectra for several flap-edge blowing pressures with a main flap blowing pressure of 1 psig for polar angles of 30, 60, and 90 degrees. The low frequency peak noise at roughly 600 Hz with no blowing is shifted to a higher frequency when the main blowing is turned on and is now at approximately 1500 Hz. This is most likely due to the increased lift caused by the main flap blowing. The increased amount of jet blowing from the trailing edge increases the high frequency noise (above 1000 Hz) substantially. These results were similar to results found at the higher main flap blowing pressure.

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Flow visualization of the vortex indicated that the effect of increasing the main flap blowing was a "strengthening" of the lift vortex. The strengthening was only assumed and not quantified. The vortex became more "vigorous" and intuitively, wing lift was increasing on the deployed flap, the vortex should have become more intense. The effect of blowing on the flap edge was observed to "push" the vortex further towards the trailing edge span. This was observed clearly with tufts. This can be seen clearly in Figure 8. This picture was taken with the camera pointed at the underneath of the wing/flap system. With no blowing from the flap edge, the tuft at the flap edge follows the vigorous motion of the tip vortex. As soon as the flap edge blowing is turned on, the vortex moves to the right in the picture from tuft labeled 1 to tuft labeled 2. The strength of the shifted vortex was not quantified but the effect on the farfield acoustics was to increase the high frequency content of the radiated noise, most likely due to the issuing air jet, while mildly affecting the low frequency content. Thus no noise benefits were observed. Additional work needs to be done on the effect of tip blowing on flap-edge noise.

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Effect of Main Flap and Flap Edge Blowing ;

$V_{Tunnel} = 100$ ft/s

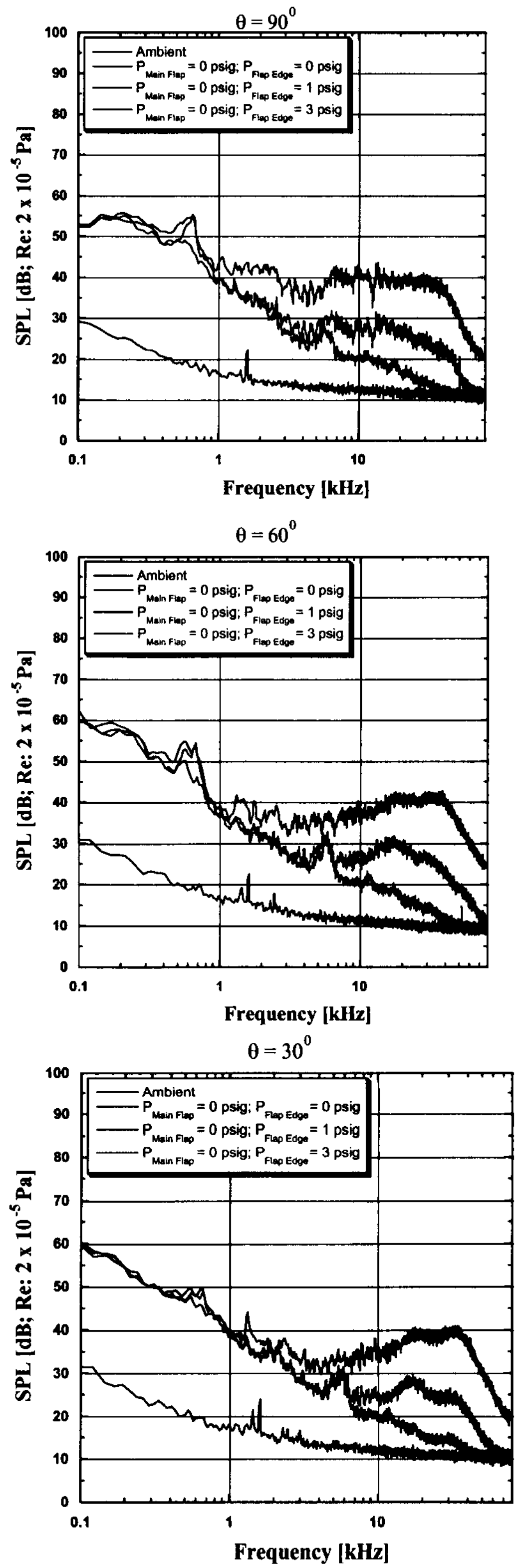

Figure 6. Effect of Flap-Edge blowing on farfield noise.

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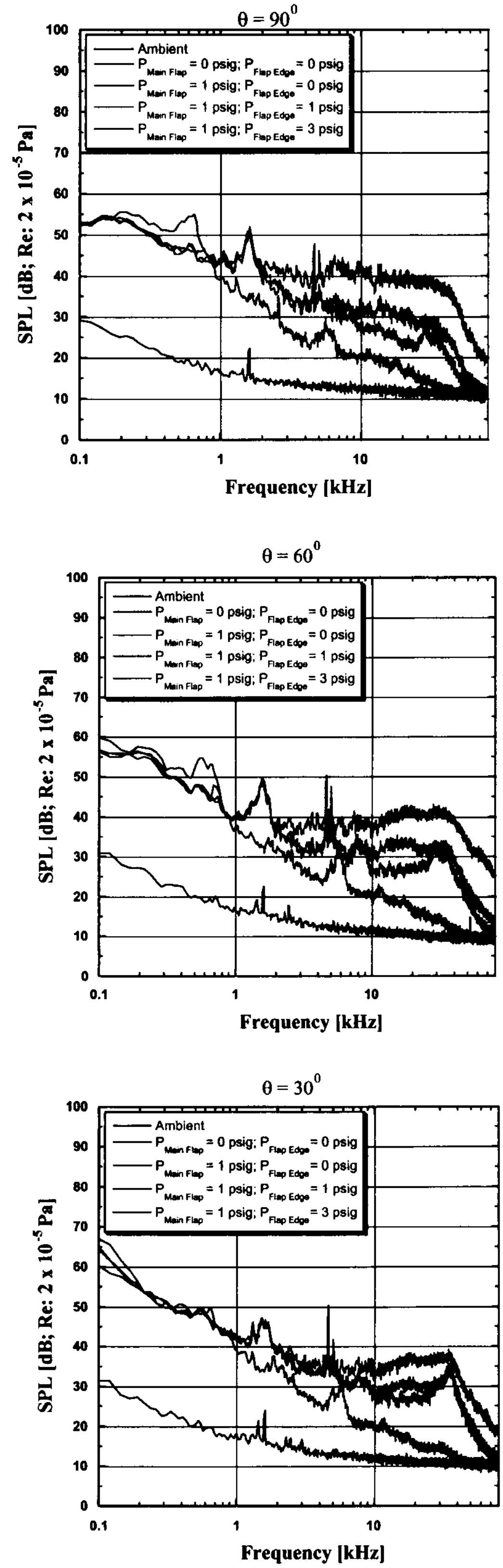
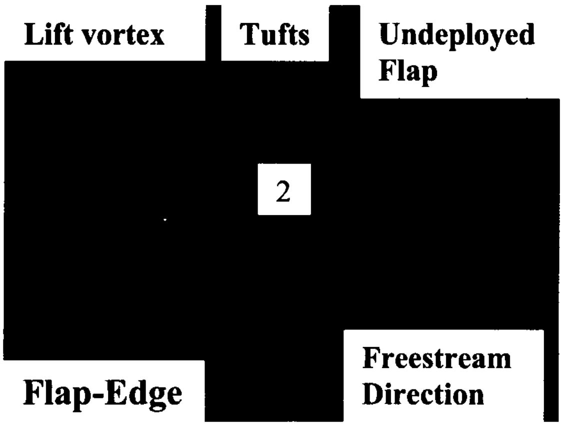


Figure 7. Effect of Flap-Edge blowing on farfield noise with main flap blowing.



No Blowing

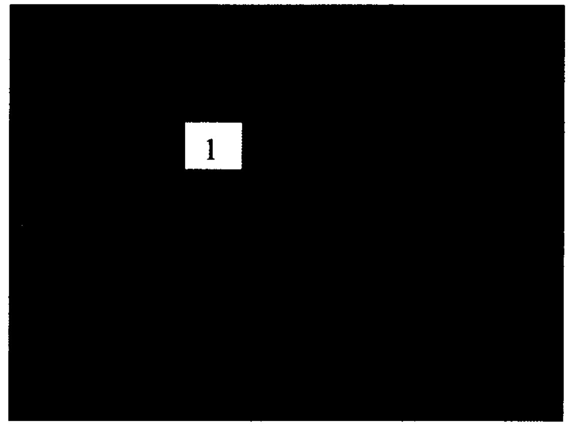


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Figure 8. Vortex moves from tuft 1 to tuft 2 on blowing from the tip of the flap edge.